

Before the
FEDERAL COMMUNICATIONS COMMISSION
 Washington, D.C. 20554

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 FEDERAL COMMUNICATIONS COMMISSION
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 Telecommunication Union World)
 Radiocommunication Conferences)
 _____)

IC Docket No. 94-31

REPLY OF HUGHES SPACE AND COMMUNICATIONS COMPANY
AND HUGHES COMMUNICATIONS GALAXY, INC.

Hughes Space and Communications Company ("HSC"), a unit of Hughes Aircraft Company ("HAC"), and Hughes Communications Galaxy, Inc. ("HCG") (collectively, "Hughes") submit this reply in response to the comments filed on the Second Notice of Inquiry ("Second NOI") in this docket^{1/} regarding the 1995 World Radiocommunication Conference ("WRC-95") and future WRCs.

It is vital to the interests of U.S. industry that the available spectrum be used in the most efficient way possible. The Commission should reject without further consideration the band segmentation approach urged for the accommodation of non-GSO links at Ka band by TRW, Motorola/Iridium and Teledesic. This approach would allow a few non-GSO systems to have a monopoly over hundreds of megahertz of spectrum to the exclusion of GSO satellite systems. Instead, the Commission should sponsor a study by both GSO and non-GSO applicants to define sharing criteria that would make GSO and non-GSO

^{1/} FCC No. 95-36 (Released January 31, 1995).

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systems compatible with each other to the fullest extent possible and thereby allow shared use of the Ka band by all competing satellite services.

I. INTRODUCTION

In its March 6 Comments, Hughes expressed concern about the Commission's current proposal with respect to non-GSO MSS feeder links at Ka band. Although Hughes acknowledged the need to make sufficient spectrum available for such feeder links, Hughes expressed reservations about the Commission's proposal to designate 500 MHz of the Ka band for co-primary use by non-GSO MSS feeder links and to remove the protections intended by RR 2613 in that portion of the band. Hughes explained that unless RR 2613 was replaced by some type of sharing criteria that ensured that GSO networks could come into service in these bands after a non-GSO system commenced service, the coordination of the first non-GSO system could result in the de facto relegation of GSO FSS systems to secondary status. As Hughes explained, the failure to adopt adequate sharing criteria at WRC-95 could (i) lead to an inefficient use of the Ka band since non-GSO MSS operators would have no incentive to share the band with other systems, and (ii) unduly constrain use of this band, which is essential for the development of next-generation satellite systems that cannot be accommodated in the currently-used C and Ku bands.

For these reasons, Hughes urged the Commission to seek to accommodate the feeder link needs of non-GSO MSS systems in portions of the spectrum where reverse band working maximizes the spectrum utilization. If the Commission nevertheless decides to make some portion of the Ka band available for non-GSO MSS feeder links on a co-directional basis, Hughes urged the Commission to base its proposal for WRC-95 on the fact that sharing between GSO FSS and non-GSO MSS feeder links is feasible with certain

constraints^{2/} and seek to develop inter-service sharing criteria that would maximize access to the band by multiple satellite systems, both GSO and non-GSO. Hughes also urged the Commission to structure and supervise the development of these type of criteria by an industry working group.

A number of parties have advanced counterproposals for feeder link use of the Ka band that go far beyond the Commission's proposal and would entirely preclude access to large segments of the Ka band by GSO FSS systems. As discussed in more detail below, it is essential that the Commission definitively determine the extent to which non-GSO and GSO systems can share the same band before considering any such proposals.

II. THE COMMISSION SHOULD REJECT PROPOSALS TO MAKE GSO SYSTEMS SECONDARY AT Ka BAND

Of the approximately thirty parties who filed comments in this proceeding, only a few supported the need to make feeder link spectrum available in the Ka band on a co-directional basis with GSO FSS systems. GE fully supported Hughes' position that the Commission should not take any actions at WRC-95 that would prevent equitable sharing of the Ka band by GSO and non-GSO systems. However, each of TRW, Motorola/Iridium, and Teledesic, three U.S. applicants for non-GSO use of the Ka band, have gone far beyond the Commission's proposal and have advocated the adoption of a regulatory scheme that would make GSO systems secondary in up to 1000 MHz in each direction at Ka band. These proposals should be rejected because they are fundamentally inconsistent with established Commission policies that encourage efficient use of the spectrum.

^{2/} This conclusion of Task Group 4/5 was reaffirmed in the Report of CPM-95, 5 April 1995.

In the Second NOI, the Commission proposed two distinct regulatory schemes. In bands below 17.7 GHz, where co-directional sharing is difficult between non-GSO MSS feeder links and GSO FSS networks, the Commission proposed to make certain FSS bands available in the reverse direction for exclusive use by non-GSO MSS feeder links. In contrast, in bands above 17.7 GHz where the Commission recognized that co-directional sharing between non-GSO feeder links and GSO networks is feasible with certain constraints, the Commission proposed a regulatory scheme that puts competing non-GSO networks on an equal, co-primary status with GSO networks.^{3/} In the bands above 17.7 GHz, the Commission also proposed that non-GSO systems would be exempt from the applicability of RR 2613 and that appropriate coordination procedures could afford successfully coordinated non-GSO systems with full protection from other users. (Second NOI at 18-23).

In their March 6 Comments, Teledesic, TRW and Motorola/Iridium seek to turn this proposed structure on its head. Instead of allowing GSO systems co-equal access to the bands above 17.7 GHz (which each of them seeks for non-GSO feeder links), Teledesic, TRW and Motorola/Iridium would take the unprecedented step of making GSO systems secondary in those bands. The following is a summary of these proposals:

Teledesic

Teledesic proposes to modify the current international Ka band allocations to make at least 1000 MHz of spectrum available in each direction primarily for non-GSO systems. GSO systems brought into service after November 1995 would be relegated to secondary status in those bands. (Teledesic Comments at 19).

^{3/} The Commission correctly noted that the availability of Ka band spectrum for feeder links would be affected by the outcome of other rulemaking proceedings. See Second NOI at 29, n. 12 to Table 2.

Motorola/Iridium

Motorola/Iridium likewise propose that 500 MHz at each of 19.7--20.2 and 29.0-29.5 GHz be reallocated primarily for use by non-GSO systems and that any GSO systems brought into service after the adoption of their proposed changes would be relegated to secondary status in those bands. (Motorola Comments at 12 & Attachment 1; Iridium Comments at 22 & Appendix 1).

TRW

TRW proposes three alternate approaches. First, TRW proposes allocating for feeder links two bands which TG 4/5 and CPM 95 summarily rejected: 29.5--30.0 and 19.7--20.2 GHz. Second, TRW endorses Motorola's proposal to designate 29.0--29.5 and 19.2-19.7 GHz for feeder links. In each of these two cases, TRW proposes establishing primary allocations for feeder links, and making secondary any GSO FSS system brought into service after November 1995. TRW's third proposal is to preserve the current primacy of GSO FSS systems at Ka band in the directions for which the band is now allocated, and allow reverse band working for non-GSO MSS feeder links in the 18.8--19.7 GHz band. (TRW proposes pairing this third option with a suitable band below 17.7 GHz).

The Commission should reject the band segmentation proposals of TRW, Teledesic and Motorola/Iridium to preclude GSO use of parts of the Ka band. These proposals to relegate GSO FSS systems to a secondary status are an unnecessary, short-sighted, and an inequitable way to allocate use of the spectrum.

First and foremost, these proposals are contrary to the policies that the Commission has developed for over two decades to ensure that U.S.-sponsored satellite systems would maximize use of the spectrum. Use of the 500 MHz in each direction that is available now for domestic use at C and Ku band has been maximized through spectrum management tools such as 2° orbital spacing, standardization of frequency plans, and the adoption of antenna performance criteria. By accepting these system design constraints, dozens of different GSO FSS systems are able to use the same spectrum to serve the same geographic areas.

Now, in the rush to obtain spectrum for their own systems, TRW, Motorola/Iridium and Teledesic would simply "lop off" 500 to 1000 MHz at Ka band for use by non-GSO systems that would have absolutely no obligation to share that spectrum with each other or with any GSO FSS system. Adopting the position of TRW, Motorola/Iridium or Teledesic would create the anomalous result that a single non-GSO system could obtain exclusive global use of 200-500 MHz of spectrum (i.e., with no requirement to share with any other system), while no U.S. authorized GSO FSS system is allowed to do the same. Indeed, any GSO FSS system applicant in the U.S. is required to demonstrate that its system can operate in a 2° spacing environment.

There is no reason to abandon the principle of shared spectrum use simply to accommodate the spectrum needs of a few. To the contrary, the same policies that would impose design limitations to ensure efficient spectrum use by GSO FSS systems at Ka band should also be developed in a form appropriate for the efficient shared use of that same band by non-GSO systems. Obviously, it is not possible to impose minimum orbital spacing requirements on non-GSO systems, but, as Hughes describes below, there is no reason that comparable spectrum sharing tools cannot be developed to facilitate non-GSO and GSO sharing and maximize use of the Ka band by multiple systems.

Moreover, the TRW, Teledesic, and Motorola/Iridium proposals should be rejected because making GSO FSS systems secondary in specific parts of the Ka band would prejudice the outcome of the Commission's pending 28 GHz rulemaking in CC Docket No. 92-297, and the Hughes Spaceway application which seeks authority to use the very bands in question. As Commission staff have correctly noted in IWG-4 meetings, the Commission cannot endorse an allocation scheme that accommodates some of the pending Ka band

applications and excludes granting of others. Since the Commission has not yet closed the filing window for Ka band applications, all currently pending applications to use the Ka band, including Spaceway, Teledesic, Iridium and Odyssey, are entitled to concurrent and comparative consideration.^{4/} The Commission therefore needs to maintain the flexibility at WRC-95 to accommodate each of these applications.

Finally, TRW is simply wrong when it alleges that its proposal to allow non-GSO MSS feeder links access to the 29.5-30.0 and 19.7-20.2 GHz parts of the Ka band is "fully consistent with the conclusions advanced in the Task Group 4/5 Report". (TRW Comments at iii). In recognition of the unique ability of the 29.5--30.0 and 19.7-20.2 GHz portions of the Ka band, which are not available for terrestrial use, to support ultra-small earth terminals that do not require prior coordination, TG 4/5 and CPM-95 quickly rejected consideration of this band for feeder links. Thus, there is no reason for the Commission to consider use of this band.

^{4/} See Ashbacker Radio Corp. v. FCC, 326 U.S. 327 (1945); see also Reply of Hughes Communications Galaxy, Inc., FCC File Nos. 15-SAT-LA-95, 16-SAT-AMEND-95, 17-SAT-LA-95, 18-SAT-AMEND-95 (filed January 13, 1995).

Motorola and Iridium allege some special claim to the 19.2-19.7 and 29.0-29.5 GHz bands because the Iridium system has been designed to use feeder link spectrum within these particular segments and Motorola has commenced international coordination. (Motorola Comments at 12, n.8; Iridium Comments at 23, n. 3). This claim is groundless. Motorola has no authority to use any specific feeder link frequency. The Commission should reject Motorola's efforts to bootstrap itself into a band by relying on activities that it has taken at its own risk. See Report of the LMDS/FSS 28 GHz Negotiated Rulemaking Committee (September 23, 1994), Addendum of Hughes Space and Communications Company and Hughes Communications Galaxy, Inc., at 7.

III. SHARING IS POSSIBLE BETWEEN GSO FSS AND NON-GSO MSS FEEDER LINKS

In its March 6 Comments, Hughes described certain sharing studies that it had sponsored to validate and extend the conclusion of TG 4/5 and CPM-95 that sharing between GSO FSS systems and non-GSO MSS feeder link systems is feasible with certain constraints. Currently, a total of nine independent sharing studies have been submitted to IWG-4.^{5/} Most of these analyses confirm Hughes' belief that the feeder links of non-GSO MSS systems can be shared with GSO FSS systems on a co-primary basis without impractical technical or operational constraints. Although Motorola has claimed that some of the interference reduction mechanisms considered in these studies would not be practical for its system,^{6/} the sharing studies attached as Exhibits 2 and 3 (which were presented to IWG 4 on April 11, 1995) confine the assumed interference reduction techniques to capabilities already present in the basic design of the Iridium feeder link networks.

The Comments of both TRW and Teledesic also support the position that sharing is possible. TRW reports that preliminary results from studies TRW has conducted on the prospect of co-frequency sharing between Odyssey and GSO/FSS VSAT systems are encouraging and that TRW firmly believes that the Odyssey system can use parts of the Ka

^{5/} See Exhibit 1.

^{6/} See Document IWG4/60.

band for feeder links without unduly constraining other FSS uses, (TRW Comments at 16).

In an advance copy of its preliminary sharing study, TRW states:

In this study, the sharing situation between the non-GSO MSS feeder link system and the GSO FSS system in the 30/20 GHz was examined. The co-direction sharing between two systems depends on their design but appears feasible.

In the case of the Odyssey system and the Advanced Satcom system, both systems can share the 30/20 GHz band due to the Odyssey satellite incorporating three independent steerable Ka-band antennas so the alternate earth station can be used during the interference period.

This conclusion is in exact agreement with the findings of the NASA study of sharing between the Odyssey system and Spaceway system reported in Document IWG-4/51 (Rev. 1) (attached as Exhibit 4).

Teledesic attaches interference analyses to its Comments that support the conclusion that the Teledesic system and the Spaceway system can share spectrum at least in the subbands proposed for the Teledesic high data rate terminals. (Teledesic Comments at 17-18).

Hughes strongly agrees with Teledesic that it is essential for the Commission to oversee the conduct of sharing studies that are designed to determine the sharing possibilities among the proposed Ka band satellite systems. (Teledesic Comments at 15-18). While the work to date of Task Group 4/5 and IWG-4 have recognized that certain mitigation techniques can be employed to allow sharing, neither group has focused its efforts on formulating specific inter-service sharing criteria.

In sum, Hughes urges the Commission to continue to seek ways to maximize use of the Ka band by both GSO and non-GSO systems. To this end, Hughes proposes that the Commission sponsor continuing studies to be carried out jointly by both GSO and non-GSO proponents to definitively determine, before the commencement of WRC-95:

- (1) the practicality of sharing among various satellite systems (GSO and non-GSO); and
- (2) the associated interservice sharing criteria that should be adopted.^{2/}

If Teledesic is correct that non-GSO systems reflect a "fundamental evolution" in satellite-based communications networks, and increasingly will share the field with GSO systems (Teledesic Comments at 5-6), it is essential that means be developed to allow these two types of systems to coexist in the same frequency bands.

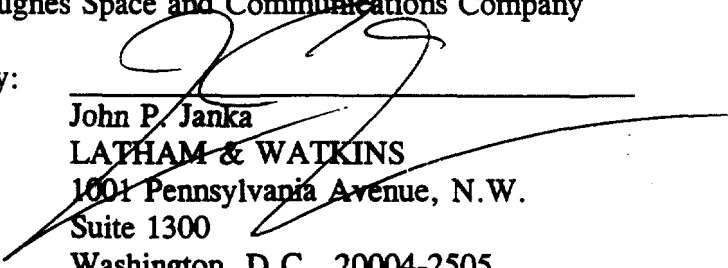
IV. CONCLUSION

Hughes acknowledges that non-GSO MSS systems need to have access to spectrum for feeder links. Nonetheless, in the rush to accommodate these systems needs, the U.S. should not advocate non-GSO/GSO band segmentation proposals that are inherently spectrum wasteful as long as better alternatives are possible, nor should it adopt a position that would preclude equitable access to the Ka band in the future by a broad range of satellite systems.

Respectfully submitted,

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^{2/} Teledesic also is correct that it is essential for the Commission, before WRC-95, to ascertain and validate the spectrum requirements of all non-GSO Ka band proponents.

EXHIBIT 1

SHARING STUDIES SUBMITTED TO IAC/IWG-4 ON GSO/FSS VS. NON-GSO/MSSFL AND NON-GSO/FSS-MSS

DOC IWG-4/	DATE	SOURCE	SUBJECT
40 Rev. 1	02/23/95	Teledesic	Teledesic-Iridium
51 Rev. 1	03/24/95	NASA Lewis RC	Spaceway-Odyssey
52	02/23/95	Teledesic	Teledesic-Iridium
53	02/16/95	Teledesic	Teledesic-Spaceway
54	02/16/95	Hughes/CSC	Spaceway-Iridium
59	02/23/95	Hughes/Bowen	Spaceway-Iridium
63	04/10/95	Teledesic	Teledesic-Odyssey
64	04/08/95	Hughes/LeClair	Spaceway-Iridium
65	03/14/95	Hughes/Bowen	Spaceway-Iridium

DRAFT FINAL REPORT

*Document IWG4/65
14 March 1995*

**The Use of Earth Station Diversity and Automatic Power Control
As Interference-Mitigation Techniques in the Sharing of Spectrum
Between the Geostationary Spaceway Fixed-Satellite System
and Feeder Links of the Iridium LEO Mobile-Satellite System**

carried out for:

Hughes Space and Communications
A Hughes Aircraft Company
El Segundo, California

by

Robert Bowen Associates Ltd.

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March 14, 1995

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**The Use of Earth Station Diversity and Automatic Power Control
As Interference-Mitigation Techniques in the Sharing of Spectrum
Between the Geostationary Spaceway Fixed-Satellite System
and Feeder Links of the Iridium LEO Mobile-Satellite System**

Summary

This report builds on the results obtained in an earlier report to Hughes Space and Communications Company entitled "Analysis of the Feasibility of Sharing Co-Directional Use of the Fixed-Satellite 19 GHz Downlink and 29 GHz Uplink Bands Between the Geostationary Spaceway Fixed-Satellite System and Feeder Links of the Iridium LEO Mobile-Satellite System". It examines the feasibility of using alternate Earth stations of an IRIDIUM Earth-station complex to avoid a potential interference event between the SPACEWAY geostationary fixed-satellite system and the feeder links of the IRIDIUM system. It is determined that if the IRIDIUM feeder-link system uses its automatic power control (APC) system to combat interference from the SPACEWAY system into its own system, then complementary use of an alternate Earth station within its Earth-station complex can avoid the instance of harmful interference in either network. The necessary separations between the Earth stations in carrying out this procedure are considerably smaller than the planned separations between the same Earth stations for other reasons.

If the IRIDIUM system were to use APC only at its Earth stations in the uplink path, the Earth-station diversity technique is still feasible; the required separations between Earth stations are somewhat larger, but still less than the separations planned for other reasons.

This technique is complementary to the space-station-diversity technique described in the earlier study mentioned above. The Earth-station-diversity technique is superior at lower latitudes where low elevation angles to GSO satellites is not a problem; the space-station-diversity technique complements that technique in that it is most advantageous at higher latitudes.

These results are then generalized to consider the sharing between IRIDIUM and other typical Ka-band GSO fixed-satellite systems, and between satellites similar to SPACEWAY and other non-GSO mobile-satellite feeder-link systems. It is concluded that the Earth-station diversity technique is applicable to avoid or reduce interference between wide classes of GSO and non-GSO systems, if the non-GSO system is in a low-Earth orbit below 1,000 km, but is less applicable if the non-GSO satellite is in a higher circular orbit in the 10,000 km altitude range.

These findings may be of use in the preparation of ITU Regulations and Recommendations relating to the sharing of bands allocated to the fixed-satellite service, between satellite systems occupying GSO and non-GSO orbits.

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**The Use of Earth Station Diversity and Automatic Power Control
As Interference-Mitigation Techniques in the Sharing of Spectrum
Between the Geostationary Spaceway Fixed-Satellite System
and Feeder Links of the Iridium LEO Mobile-Satellite System**

1.0 Introduction

The work reported on in this document was done by Robert Bowen Associates Ltd. (Bowen) for Hughes Space & Communications (Hughes), a unit of Hughes Aircraft Company. The question addressed in the work reported here is the possibility of using Earth station diversity techniques, ie. the use of alternate Earth station antennas at slightly different locations, combined as necessary and appropriate with the use automatic power control systems, to avoid potential interference events between the geostationary SPACEWAY fixed-satellite system and the feeder links of the IRIDIUM non-geostationary mobile-satellite system.

The work reported on here is a continuation of earlier work done on the same general subject of the sharing of spectrum between SPACEWAY and IRIDIUM, reported by Bowen to Hughes on March 8, 1995 in a report entitled " Analysis of the Feasibility of Sharing Co-Directional Use of the Fixed-Satellite 19 GHz Downlink and 29 GHz Uplink Bands Between the Geostationary Spaceway Fixed-Satellite System and Feeder Links of the Iridium LEO Mobile-Satellite System", (Reference 1).

The work reported here was done within the context of the following general objectives:

to investigate the feasibility of using fixed-satellite radio spectrum simultaneously in the same direction in the Ka-band by SPACEWAY geostationary fixed-satellite systems and by feeder links of IRIDIUM mobile-satellite systems, and

to explore the possible use of interference mitigation techniques to enable the two classes of satellite network to share the use of the same spectrum bands.

The specific questions addressed in the work reported on here are:

What is the potential of using Earth station diversity techniques as an interference-mitigation measure which would permit spectrum in the 30 GHz and 20 GHz frequency ranges to be used simultaneously in the same direction by the geostationary SPACEWAY system and the feeder links of the low-Earth-orbiting IRIDIUM SYSTEM ?

and

To what extent is it necessary for the automatic power control (APC) sub-system of the IRIDIUM system to be involved in this interference-mitigation process ?

The detailed analysis carried out to answer these questions is described in Annex D of this report. To make this report a stand-alone document, rather than requiring the reader to refer to and use in

Robert Bowen Associates Ltd.

detail Reference 1, Annexes A, B, and C of that earlier report are provided here as Annexes A, B, and C of this report. Annex A is a description of the characteristics of the SPACEWAY and IRIDIUM systems provided by Hughes. (The analysis reported in Reference 1 and in this report is based entirely on that information.) Annex B is an analysis of the uplink and downlink noise budgets of the SPACEWAY and IRIDIUM feeder-link systems, based on the information in Annex A. Annex C is an analysis of the worst-case carrier-to-interference (C / I) ratios in the uplink and downlink of each system during short periods of time in which the two satellites are in line with the Earth station involved in the interference process (in some cases a SPACEWAY Earth station, but usually an IRIDIUM Earth station.) This worst-case C / I analysis is done for two cases:

1. When the IRIDIUM system uses its APC power reserve only to overcome rain attenuation, and
2. When the IRIDIUM system uses its APC power reserve also as an interference-mitigation technique, specifically to increase the transmitted power levels in its Earth stations and/or its spacecraft to overcome the transient high levels of interference from the SPACEWAY system.

Annex D analyses in detail the possibility of using alternate nearby IRIDIUM Earth stations during the short periods of time in which the primary Earth station would be involved in an interference event. The basis for examining this possibility is the high discrimination or resolution of the large IRIDIUM Earth station antennas, and the fact that an IRIDIUM Earth-station complex includes three Earth stations with these large antennas, at locations separated in the order of 37 miles.

2.0 Analysis Approach Used To Determine The Necessary Separation Between IRIDIUM Earth Stations Such that Interference Between the Two Networks Is Not Harmful

The starting point of the analysis in this report is the carrier-to-interference (C / I) equations in Annex C. These equations are generalized to be valid for offset angles of all antennas involved in the process. The resulting general equations, or re-simplifications of them as required, are used to determine the necessary angles off boresite of the IRIDIUM Earth station or satellite antennas to achieve enough isolation between the two networks that the transient interference does not prevent operation of the networks. Concentration is directed primarily on the necessary off-boresite angles of the IRIDIUM Earth station antennas, because they are the most directive antennas of either network in the process. Using the known antenna-discrimination characteristics of the IRIDIUM Earth-station antennas, the necessary off-boresite angles θ are determined to protect the IRIDIUM system, and to protect the SPACEWAY system, for each of the following two scenarios:

- i) that in which the IRIDIUM system implements its APC system to the full extent necessary to counteract interference from the SPACEWAY system, and

- ii) that in which the IRIDIUM system holds its automatic power control (APC) system in reserve to be used only to counteract atmospheric and rain attenuation.

The orbital characteristics of the IRIDIUM and SPACEWAY systems are then used to translate these required angle separations into required distance separations on the ground between two IRIDIUM Earth stations used in the mitigation process. These results are applied to suggest the necessary separation of Earth stations in an IRIDIUM Earth-station complex in which there are three Earth-station antennas, to determine how this interference-mitigation process can be used at IRIDIUM Earth-station complexes to avoid interference events involving the SPACEWAY system. The results are then generalized to consider how the process could be used to avoid interference between IRIDIUM and a number of geostationary (GSO) fixed satellite networks, all of which may be occupying different locations in the geostationary orbit.

3.0 Analysis Results

The analysis described in Section 2.0 above was completed as planned. It is described in Annex D. The results of that analysis are described in this section of the report, and are then discussed in following sections and conclusions are reached.

3.1 Required IRIDIUM Earth-Station Separation When APC In the IRIDIUM System Is Used as an Interference-Mitigation Measure

As indicated in the introduction, the characteristics of the systems analyzed are described in Annex A, their noise budgets are discussed in Annex B, and the worst-case interference C/I 's at the peaks of interference bursts lasting a few seconds involving the two systems is described in Annex C. In Annex D the following question is answered:

If the APC sub-system of the IRIDIUM feeder-link system is used to the extent possible to reduce or eliminate harmful interference into the IRIDIUM system, what separations of IRIDIUM Earth stations would be required to remove the residual harmful interference in the IRIDIUM system, and to also remove the interference in the SPACEWAY system caused by the use of the IRIDIUM system's APC to reduce its own interference?

The first step in answering this question was to determine the angular separation between the boresite of the IRIDIUM Earth station antenna and the SPACEWAY GSO satellite such that interference between the two networks is not harmful, ie. such that the $C/(N+I)$ of both uplink and downlink of both networks is above the levels necessary for successful detection of their desired signals. In carrying out this step it is assumed that the IRIDIUM satellite is in the boresite of the IRIDIUM Earth-station's antenna.

The following angle separations are required in this scenario:

- * To protect the IRIDIUM system in the uplink: 0°.
- * To protect the IRIDIUM system in the downlink: 0.24°.
- * To protect the SPACEWAY system in the uplink: 0.31°, and
- * To protect the SPACEWAY system in the downlink: 0.32°.

There is no harmful interference in this link when APC is used in the IRIDIUM system .

The largest of these four angular separations, 0.32 °, would be required if all four links were to not suffer harmful interference. It is noted in Section D.6.3 of Annex D that these angles are determined on the assumption that the IRIDIUM satellite is on an orbital path such that at one instant during its flight along that path the IRIDIUM Earth station, the IRIDIUM satellite, and the SPACEWAY satellite are in a straight line. If there were only two Earth stations involved in the interference mitigation process there would be other nearby paths that would require larger separations between Earth stations. However, when there are three IRIDIUM Earth stations involved, in roughly a straight line, the above path directly through a line joining the central Earth station and the GSO SPACEWAY is the path that requires the greatest separation between Earth stations. The required angle to be achieved by that separation is 0.32 °, as explained above.

If the IRIDIUM satellite were at the zenith as observed at the IRIDIUM Earth station, the necessary separation between the Earth stations would be $780 * 0.32^\circ * (\pi / 180)$ km. or 4.36 km. If the elevation angle of both the satellites is θ at the time of the potential interference event, then the length of the path to the IRIDIUM satellite is $780 / \sin(\theta)$ km, and so the required distance between the Earth stations would be $4.36 / \sin(\theta)$ km. This assumes the optimum situation of the line joining the two Earth stations being perpendicular to the line joining one of the Earth stations and the GSO satellite. If instead the GSO satellite and the two satellites were in a vertical plane, the effective distance between them would be further reduced by a factor $\sin(\theta)$, so the distance between them would have to be

$$d_{SEP} = 780 * 0.32^\circ * (\pi / 180) / \sin^2(\theta) \dots\dots\dots (1).$$

The stated minimum elevation angle of the SPACEWAY system in CONUS is 30°, so the maximum required value of d_{SEP} would be 17.44 km or about 9.42 nautical miles.

The planned layout of an IRIDIUM Earth station complex includes a central Earth station and two peripheral Earth stations about 39 nautical miles away in roughly opposite directions, (see Figure 1, obtained from Hughes on January 23, 1995) so this requirement of a 9.42 nautical mile separation between Earth stations could easily be met by the IRIDIUM system as currently planned.



Figure 1
A Typical IRIDIUM Earth Station Complex

3.2 Required IRIDIUM Earth-Station Separation When APC In the IRIDIUM System Is Not Used as an Interference-Mitigation Measure

In examining this scenario the above procedure was repeated, except that the carrier levels in the IRIDIUM system are assumed to be only great enough to achieve a C/N of 10.7 dB. If the reserve Earth station and satellite power were not utilized by the IRIDIUM system during an interference event to improve the $C/(N+I)$ of its own system, the worst-case C/I in the uplink portion of the system would be -14.3 dB, equivalent to a negative margin of 25.0 dB. In the downlink, the worst-case C/I would be -9.6 dB, equivalent to a negative margin of 20.3 dB.

In contrast, the worst-case C/I in the uplink of the SPACEWAY system would be +14.2 dB, well above the required minimum $C/(N+I)$ of 6.9 dB, and the worst-case C/I in the downlink of the SPACEWAY system would be +10.2 dB. Any Earth-station diversity employed by the IRIDIUM system to improve its own interference budgets would simultaneously improve the C/I budgets of the SPACEWAY system above those +14.2 dB and +10.2 dB in the uplink and downlink respectively.

In the uplink, the antennas that affect the interference level in the IRIDIUM space station are the SPACEWAY Earth station antennas and the IRIDIUM space station antenna. Given that there would be thousands of small user's Earth terminals in the SPACEWAY system, it would not be possible for these terminals to all have alternate antennas many miles away. Note that the separation distances would be much larger than that required for the IRIDIUM Earth stations, because the SPACEWAY Earth terminal antennas have beamwidths in the order of 1.1° rather than the 0.24° beamwidth of the IRIDIUM system. Thus use of alternate SPACEWAY Earth terminals is ruled out as an interference-mitigation measure.

The alternate approach in the uplink is to rely on the antenna-discrimination characteristics of the IRIDIUM spacecraft antenna, and place an alternate IRIDIUM Earth station at the appropriate location to transmit to the re-directed IRIDIUM spacecraft antenna. In the uplink the IRIDIUM spacecraft has a 5° beam. To achieve a 25 dB isolation with such an antenna, to raise the IRIDIUM uplink C/I to 10.7 dB, so that the uplink $C/(N+I)$ would be the minimum 7.7 dB, the interference would have to be 27° off the boresite of the IRIDIUM antenna. This would require, as a minimum, Earth station separations in the order of 844 km at locations where the SPACEWAY satellite's elevation angle was 30° . Such separations are not considered practical. The direct conclusion from these findings is that neither Earth terminal antenna discrimination nor spacecraft antenna discrimination are practical techniques when used alone to reduce the uplink interference into the IRIDIUM system to workable levels.

In the downlink the situation is considerably better. The antenna controlling the magnitude and duration of the interference in that link is the receiving IRIDIUM Earth station antenna. In the downlink the worst-case interference is -9.6 dB. To raise the worst-case C/I ratio to +10.7 dB so that